IDA

INSTITUTE FOR DEFENSE ANALYSES

Visit to China's ARJ21 Aircraft Manufacturing Facility

Stephen J. Balut, Project Leader

David L. McNicol
J. Richard Nelson
Bruce R. Harmon
Stephen G. Holder

April 2008

IDA Document D-3546
Log: H 08-000384

INSTITUTE FOR DEFENSE ANALYSES

IDA Document D-3546

Visit to China's ARJ21 Aircraft Manufacturing Facility

Stephen J. Balut, Project Leader

David L. McNicol
J. Richard Nelson
Bruce R. Harmon
Stephen G. Holder

PREFACE

The Institute for Defense Analyses (IDA) prepared this document under IDA's independent research program. The document describes what an IDA delegation saw and heard during a December 2007 visit to the Shanghai Aircraft Manufacturing Facility where the commercial Chinese ARJ21 flight test aircraft was being assembled.

The material has not been evaluated, analyzed, or subjected to formal IDA review.

TABLE OF CONTENTS

A. INTRODUCTION

Members of the Institute for Defense Analyses (IDA) and the Aviation Industry Development Research Center of China (ADR) meet periodically to exchange ideas and information on topics of mutual interest with the purpose of improving mutual understanding and reducing misunderstandings between the United States and China. No classified information is exchanged or discussed during these meetings.

For two decades, a mainstay in these discussions has been methods of estimating the costs to develop and produce civilian aircraft. China had a stated intent to produce a 100-passenger civilian aircraft for use in China. ADR was unsure what that might cost and asked IDA to share analytical methods for estimating such costs. IDA was interested in China's capability to design and manufacture aircraft and the relative cost of production between the West and China.

As a result, IDA shared basic methods for estimating the life-cycle costs of civilian aircraft. ADR shared plans for developing the 100-passenger aircraft and took IDA delegations to aircraft manufacturing facilities in China to observe existing facilities, practices, and capabilities. IDA members were told ADR applied IDA's analytical methods while estimating the costs of the aborted AE100 program and also the ARJ21 program.

IDA's most recent interaction with ADR occurred in December 2007. A delegation of IDA staff members visited the ADR facility in Beijing where IDA-led discussions focused on operating and support costs of civilian aircraft and ADR-led discussions focused on cost experience to date on the ARJ21 civilian passenger aircraft program. Following discussions in Beijing, the ADR hosts took the IDA delegation[1] to Shanghai to see the ARJ21 at its assembly facility, the Shanghai Aircraft Manufacturing Facility (SAMF) and provided a briefing on progress. Our tour of SAMF lasted about 2 hours.

The following paragraphs describe our observations about the facility we visited; the flight test aircraft we saw; and what we learned about the design, manufacturing, organization, and management of the ARJ21 program.

---

[1] The IDA delegation (the authors of this document, listed on the cover) was accompanied by Yin Yunhao, President Assistant, Aviation Industries of China (AVIC) 1, and Huang Weijia, Deputy Director of ADR. The SAMF official who led the facility tour was Wang Yawei, Vice President, Commercial Aircraft, AVIC 1. He was accompanied by the Chief Engineer for the ARJ21 program.

B. MANUFACTURING FACILITY

We saw many new buildings both completed and under construction at the SAMF.

A large windowed building housed the management offices and a board room where the Chief Engineer gave our delegation a presentation on the background of the program.

The building where final assembly of the ARJ21 would take place was not large enough to house the assembly line needed to produce at a rate of 30 (by 2009) to 50 units per year. The building was nearly empty. That is, there was no assembly line. We saw one set of simple assembly tooling. presumably the tooling used to mate the flight test aircraft's major subassemblies. Our hosts reported they would have to build other facilities on the compound to be able to attain the 30-per-year rate. They said additional land adjacent to the current facilities might be acquired to expand capacity.

Another building housed the "iron-bird" aircraft subsystems test fixture, a flight simulator, and the software system integration laboratory. At the iron-bird, they demonstrated the lowering of the front landing gear. Subsystem tests were being run by the First Aircraft Institute (FAI). Two U.S. contractors from General Electric, Cincinnati, were flying the simulator while Chinese engineers, believed to be from FAI, observed. Systems other than main flight controls (e.g., landing gear) were not hooked up in the simulator. In the laboratory, we saw a pilot station that was set up for training new pilots. U.S. contractors from Rockwell Collins in Iowa were working to install equipment at this station.

Another building contained the production line producing horizontal stabilizers for Boeing 737s. The line was producing 21 stabilizers per month and another 7 per month were reportedly being produced at another location in China. A machining facility was reported to be elsewhere on the grounds. This contrasted to the situation observed during IDA's 1996 visit, when much of the machining and assembly work was co-located in a single building at SAMF.

The paint shop (a separate building) contained no automated painting equipment.

A new building still under construction was intended to provide support logistics for the program infrastructure.

C. ARJ21 AIRCRAFT

The first two aircraft, the static and fatigue test articles, were in Xian. The ARJ21 #3, the flight test article we saw at SAMF, was close to completion. The aircraft was in the paint shop being readied for painting. We did not see inside the aircraft. Our hosts reported that neither electrical-mechanical equipment installation nor software integration had yet been completed.

The parts of the aircraft that would not be painted (e.g., landing gear) had been wrapped in paper and taped over. Workers were dusting off the metal surfaces with cloths. The workers wore cloth coverings over their shoes and used safety ropes attached to their belts while walking on the aircraft.

Mating of airframe subassemblies at SAMF reflected a low state of maturity in multi-site integration. There were significant gaps and overlaps to be addressed.

At the iron-bird facility, we saw a chart that indicated that completion of certain parts of the aircraft's assembly lagged behind others. The two areas with the least progress were electronic integration of mechanical and internal functions (two stars out of a possible ten).

D. AIRCRAFT DESIGN

The FAI has design responsibility for the aircraft. FAI is located in Xian and has teams at SAMF to oversee ground testing activities.

Antonov Aeronautical Scientific/Technical Complex (ASTC) contributed to the design of the wing and conducted wind-tunnel testing of the wing.

When asked about the degree of design tool integration between the contributing manufacturing sites, Yin Yunhao stated that all sites were using some kind of Computer Aided Design (CAD)/Computer Aided Manufacturing (CAM)/Computer Aided Three-dimensional Interactive Application (CATIA) system, and although the separate systems were not integrated, they were able to share design data. He said a fully integrated system shared between manufacturing sites was a goal.

E. MANUFACTURING PROCESS

Major subassemblies were built in various locations:

- Fuselage and wings—Xian Aircraft Company (XAC)
- Nose—Chengdu Aircraft Corporation (CAC)

- Empennage, pylons, vertical stabilizer—Shenyang Aircraft Corporation (SAC)
- Radome—Research Institute for Special Structures of Aeronautical Composites (RISAC) Jinan
- Horizontal Stabilizer—SAMF

We heard conflicting reports as to where the first two articles (static and fatigue) were assembled, Xian or Shanghai. The most logical place would be Xian.

Our hosts reported that the basic mate of major subassemblies went well, but they reported difficulties in other areas (e.g., subsystem installation and integration).

Our hosts said all wiring for the aircraft was performed in Shanghai. In an earlier question and answer discussion, Yin Yunhao indicated that the ARJ21 was following the Airbus method of mating "stuffed" subassemblies vice the Boeing method of stuffing the aircraft at final assembly. He backtracked on this statement once it was clear that the ARJ21 was following the Boeing method more closely. (A possible source of confusion could have been that the earlier AE100 concept followed the Airbus method.)

We were told Rockwell Collins has complete responsibility for avionics integration. We observed employees from Rockwell Collins installing equipment in the software system integration laboratory.

While observing production of Boeing 737 horizontal stabilizers, we noted that the products at the end of the production line were of good quality. In the earlier stages, there had been signs of difficulties with rivets and rivet holes. The overall organization of the subassembly manufacturing operation appeared substantially better than we had observed during our 1996 visit to SAMF.

F. ORGANIZATION AND MANAGEMENT

The ARJ21 is believed to be China's first attempt to integrate major efforts across multiple government organizations and private sector enterprises and manufacturing sites. Prior to this effort, production of both military and civilian aircraft was the domain of a single site and each individual site viewed itself as being in competition with other sites. Very broadly, the ARJ21 design work seems to be in the hands of government organizations and the aircraft's manufacturing work in the hands of private sector organizations.

The ARJ21 poses challenges in at least two dimensions—organizational and technical. The organizational challenge is that 25 to 30 distinct organizations are

involved in the program. The main technical challenge is integration of inputs from multiple organizations and sites.

The organizational problem was addressed through creation of a new entity, AVIC Commercial Aircraft Company (ACAC), headquartered in Shanghai. We were told the ACAC was organized to manage the development and production of the ARJ21 with the presumption that it would go on to develop and produce other civilian aircraft. It is to be the Boeing of China. A newspaper article we saw during our visit announced that ACAC would begin development of a "large aircraft," perhaps the size of a 737, to go on line in 2020.[2]

ACAC serves as the coordinating body for the different research institutes and manufacturing sites involved. The extent to which ACAC can actually hold the other organizations responsible was not clear. We do not fully understand the contracting relationship between ACAC and the manufacturing sites (i.e., how price is determined and terms and conditions under which hardware is delivered from manufacturing sites to ACAC). We were told "ACAC sets price targets for the sites." The ultimate decisionmaking authority on the ACAC and the ARJ21 appears to be the Central Military Commission (CMC), but the lines from the CMC to AVIC 1 to ACAC are not transparent.

When we continued to ask about organizational arrangements (i.e., suggesting that maybe there were too many cooks in the kitchen), our hosts told us that they recognized the current organizational arrangement was unsatisfactory and that a reorganization was expected.

The technical challenges posed by the integration effort were addressed to some extent through the sharing of digital design data. ACAC stated a goal of developing a fully integrated system for sharing design and manufacturing data. Some members of the IDA team suspected that FAI had been modeled after the Soviet Design Bureau (SDB) concept and shortcomings of the integration effort were a manifestation of the design bureau/manufacturing plant model used by the Soviet Union. However, a major difference is that ACAC has responsibility for development and production of the design,

---

[2] This information has been widely reported since. See, for example, Bradley Perrett, "Chinese Earmark US$8B For Large Civil Aircraft," Aviation Week, January 31, 2008 (http://www.aviationweek.com/aw/generic/story_channel.jsp?channel=comm&id=news/CHIN01318.xml).

whereas the SDB had responsibility for the development before turning it over to a production factory.

G. OTHER ISSUES

Sometime around December 2007, the first flight of the aircraft—presumably from Shanghai to Xian where flight testing will be conducted with Boeing consulting—was moved forward from December 2007 to March and then to April 2008. The cause of the delay was reportedly due to weight growth of the aircraft. Weight was reported to be a problem during the design phase, according to press releases in May 2006. The fuselage was not delivered from Xian until February 2007 with final mate completed in June 2007. AVIC 1 likely was aware of the delay long before it was publicly acknowledged. Some members of the IDA team suspected first flight would not occur until late 2008.

Rockwell Collins has complete responsibility for avionics integration. It appears unlikely that the Chinese will be given access to the software code.

General Electric provides the CF-34 engines for the ARJ21 and is a risk-sharing partner with an investment of $90 million. The Chinese reportedly thought this was a good deal as it was struck shortly after 9/11.

When we asked about plans to buy engine spares once the aircraft was in full production, it appeared our hosts had not considered this yet, but they said they would probably budget for a 5-percent spare (engine) parts ceiling.

They had not developed plans to place trained maintenance personnel at airports. During our cost estimating workshop the day before, ADR identified marketing and customer support as large hurdles that needed to be overcome if the ARJ21 was to be an economic success. Reportedly, one reason AVIC 1 took on Airbus as a partner in its aborted AE100 project was to assist in these areas.

H. CONCLUSION

All members of the IDA delegation are in agreement that the ARJ21 program is an experiment in combining government and private sector organizations. China appears to be moving towards establishment of a national champion in the world-wide aircraft industry by integrating the strongest aspects of its various research institutes and manufacturing sites into an integrated enterprise. The ARJ21 program could be considered a prototype for this approach.

ABBREVIATONS

ACAC	AVIC Commercial Aircraft Company
ADR	Aviation Industry Development Research Center of China
ASTC	Aeronautical Scientific/Technical Complex
AVIC	Aviation Industries of China
CAC	Chengdu Aircraft Corporation
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CATIA	Computer Aided Three-dimensional Interactive Application
CMC	Central Military Commission
FAI	First Aircraft Institute
IDA	Institute for Defense Analyses
RISAC	Research Institute for Special Structures of Aeronautical Composites
SAC	Shenyang Aircraft Corporation
SAMF	Shanghai Aircraft Manufacturing Facility
SDB	Soviet Design Bureau
XAC	Xian Aircraft Company

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
XX-04-2008	Final	Oct 2007-Apr 2008

4. TITLE AND SUBTITLE
Visit to China's ARJ21 Aircraft Manufacturing Facility

5a. CONTRACT NUMBER
DASW01-04-C-0003

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S), Last Names First
Balut, Stephen J.
McNicol, David L.
Nelson, J. Richard
Harmon, Bruce R.
Holder, Stephen G.

5d. PROJECT NUMBER

5e. TASK NUMBER
C0019

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Institute for Defense Analyses
4850 Mark Center Drive
Alexandria, VA 22311-1882

8. PERFORMING ORGANIZATION REPORT NUMBER
IDA Document D-3546

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Institute for Defense Analyses
4850 Mark Center Drive
Alexandria, VA 22311-1882

10. SPONSOR/MONITOR'S ACRONYM(S)
IDA

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

During a December 2007 visit to China to share information about civilian aircraft costs, a delegation from IDA visited the Shanghai Aircraft Manufacturing Facility where the commercial Chinese ARJ21 flight test aircraft was being assembled. The ARJ21 is a DC-9–sized civilian passenger aircraft with first flight currently scheduled for late 2008. This document describes the delegation's observations about both the facility and the aircraft they saw. It also explains what delegation members learned about the design, manufacturing, organization, and management of the ARJ21 program.

15. SUBJECT TERMS
ARJ21 Aircraft; China; Commercial Aircraft; Aircraft Manufacturing; Manufacturing Costs; Aviation Industries of China (AVIC); Shanghai Aircraft Manufacturing Facility (SAMF); Test Aircraft

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON (Last Name First)
a. REPORT	b. ABSTRACT	c. THIS PAGE			Balut, Stephen J.
Unclassified	Unclassified	Unclassified	Same as Report	13	19b. TELEPONE NUMBER (*Include area code)* 703-575-1431